Valuing Food Safety and Nutrition

EDITED BY
Julie A. Caswell

Book Originally Published by
Westview Press, Boulder, Colorado, 1995

PART ONE: Setting the Stage: Research Perspectives and Theoretical Models

3. Mitigation, Product Substitution, and Consumer Valuation of Undesirable Foodborne Effects

Robert D. Weaver

Food Marketing Policy Center
Department of Agricultural and Resource Economics
University of Connecticut

Mitigation, Product Substitution, and Consumer Valuation of Undesirable Foodborne Effects

Robert D. Weaver

Keywords: Foodborne illness, mitigation, consumer valuation, product substitution

3

Mitigation, Product Substitution, and Consumer Valuation of Undesirable Foodborne Effects

Robert D. Weaver

A subtle and often overlooked revolution commenced in the U.S. during the 1960s and has spread globally while simultaneously penetrating deeper and deeper layers of our social fabric. This revolution was one of consciousness of externalities. It began with recognition of the most obvious: smoke belching factory stacks and bus exhausts. Within this rubric, consciousness of the health implications of diet and food characteristics has steadily evolved targeting both general dietary effects on health as well as specific impacts of known and unknown, expected and unexpected characteristics and effects of food. Concern has included all things "artificial," for example additives such as colorants, flavorings, and other chemical residues; as well as undesirable "natural" things, for example foodborne pathogens such as aflatoxins, bacteria, molds, fungus; and other unwanted attributes which have direct health implications. Importantly, cause for consumer concern has evolved such that this list of undesirable things "natural" has been extended to include a wide variety of nutrients such as fat, sodium, calories, absence of fiber or vitamins, cholesterol, etc. The existence and value of the market for artificial sweeteners as well as egg and dairy substitutes attest to the significance of this trend in consumer concern and its manifestation in the marketplace. An underlying feature of these consumer concerns is their focus on what we will define as *undesirable foodborne effects* or UFBEs. UFBEs can be classified into three categories: (1) nutrients and nutritive characteristics, (2) food additives and residues, and (3) foodborne pathogens. This classification will prove useful in the consideration of the microeconomics of consumer valuation of changes in UFBEs.

Cook (1989) provided a general chronicle of consumer concern for various types of UFBEs. More specific evidence has evolved over the decade through a series of consumer surveys. Most recently, surveys have provided evidence that consumers have high levels of concern for possible health risks of chemical residues on fresh produce (Zind 1990, Ott and Maligaya 1989, Food Marketing Institute 1989, Sachs et al. 1987, Weaver et al. 1992). These apparently high levels of consumer concern have offered economists an attractive challenge to consider consumer behavior with respect to UFBEs. Of equal interest to economists has been measurement of consumer valuation of safety in food associated with the absence of UFBEs, whether consumer valuation is sufficiently stable to finance private sector innovation, and whether there is an opportunity for Pareto improvement from some type of government intervention.

The objective of this chapter is to consider what guidance microeconomics has to offer for valuation of UFBEs. In particular, the chapter both reviews and extends existing literature by drawing on applied microeconomic theory to consider means of measuring consumer valuation of UFBEs. In the process, the chapter will lay a microeconomic foundation for valuation of UFBEs which may be of some usefulness for further empirical studies. The plan of the chapter is as follows. The salient features of the consumer choice problem are reviewed and three cases are identified for consideration: (1) an exogenous change in health risk information affects all food and the consumer has no opportunity to avoid exposure to the risk (no mitigation), (2) an exogenous change in health risk of one food product or type is announced for a temporary period, however, risk can be managed through defensive action (partial mitigation), and (3) alternative food products are characterized by different levels of perceived health risk allowing the consumer to completely avoid exposure (full mitigation). A brief review of literature suggests that past literature has focused on Cases 1 and 2. The microeconomics of the three cases are considered and a generalized approach is presented that incorporates salient features of the consumer choice problem. Based on this generalized model, implications for measurement of consumer valuation of UFBEs are derived. Results indicate that cost-of-illness, averting expenditure, and disutility of illness are each components of willingness to pay (WTP). Importantly, the chapter demonstrates that none of these individual components will, in general, suffice to measure WTP. Availability of alternative goods free of UFBEs renders willingness to pay discontinuous in the UFBE parameter. Limits on the usefulness of premia for uncontaminated food as a measure of WTP are also established.

To clarify the focus of this chapter, two types of consumer response to UFBEs have been recognized in past literature. These include (1) consumer response to new information or announcements concerning UFBEs present in particular foods and the effects of the UFBEs and (2) demand response to and valuation of known levels of UFBEs. The first type of study considers the impact on consumer behavior of a change in information that results in an exogenous change in the perceived level of UFBE and foodborne risk associated with the food. For this reason, we label this type of study an announcement study.

Announcements have affected all types of UFBEs and by definition involve UFBEs for which exposure after announcement can be in some sense managed by the consumer. For example, announcement of the presence of or health impacts of nutritional characteristics, additives, or residues may lead to shifts in demand for affected products. Similarly, announcements concerning the presence of foodborne pathogens may influence future consumption decisions to substitute other foods for which perceived risk is lower. The second type of study, demand response to and valuation of known levels of UFBEs, is of particular interest in this chapter and presumes that available information concerning UFBEs has not led to termination of consumption of the food. Of interest in this case is how available information influences the consumer's decisions.

Microeconomics of Consumer Valuation of UFBEs

In order to construct the microeconomic basis for measuring consumer valuation of changes in UFBEs, three cases will be considered which emerge from different interpretations of externalities and their effects that are associated with UFBEs. Each of the cases is relevant for particular types of UFBEs.

For the first case, the UFBE is specified as an externality that is purely exogenous in origin. As in the classic Pigouvian case, no mitigating reaction by the affected individual is allowed. An unexpected exposure to a foodborne pathogen is a UFBE that falls in this case. Under such conditions, the microeconomics of consumer valuation of a change in the externality is straightforward. For the second case, we differentiate exposure to an externality from the effect of an externality, allowing for partial mitigation by those exposed. Clearly, in many cases of externality, the decision-maker has an opportunity to react by adapting decisions to reduce the impact of the externality. This type of partial mitigation is not possible in Case 1. As Shibata and Winrich (1983) noted, the polluted must be expected to defend themselves. UFBE examples that would fall into this case would include presence of chemical pesticide residues on the surface of produce. Here, washing or peeling could reduce exposure dramatically while allowing the consumer to continue to consume the product. The third case follows when full mitigation or avoidance is feasible, as is often possible with respect to exposure to UFBEs. In such a case, the consumer can choose alternative products and avoid exposure.

The microeconomics of Case 1 are well-known (see, e.g., Swartz and Strand 1981) and will be considered only briefly here. In each of the second and third cases, a microeconomic perspective will be presented on the question of valuation of changes in the level of exposure to a UFBE, which is viewed as an externality associated with food consumption. In particular, alternative indicators of value will be considered: cost-of-illness, defensive or averting expenditures, and willingness to pay. In a final model, the features of Cases 2 and 3 are synthesized to produce a general microeconomic model capable of analyzing observed consumer choice.

Before proceeding, one further bit of housekeeping must be completed to clarify the focus of the chapter. In particular, any externality, including the UFBEs to be considered here, may be either an expected characteristic of a situation or it may be a randomly occurring characteristic. For the case of UFBEs, expected characteristics might include the known, expected, or perceived health effects of sugar, fat, or a chemical residue. Randomly occurring characteristics generated by known probability density functions would include health effects resulting from known pathogens and are properly labeled *food-borne risks*. Where the pathogen's presence is unknown, uncertainty—not risk—would exist. This chapter will consider only the first type of effect. Generalization of the theory to allow for random effects is straightforward.

Case 1: Exogenous Externality with No Mitigation

In this case, the extent of exposure to the externality is presumed known and exogenous to the individual. Where the effect of the exposure is also known, a variation of the Swartz and Strand (1981) model can be used to consider the implications of this case. In their model, two goods are assumed X_1 and X_2, where the quality of X_1 is indicated by $Z_1 = Z_1(N)$ where N indicates the state of information concerning quality. X_1, X_2, and N are assumed available in perfectly elastic supply to the individual at prices P_1, P_2, and c. The individual is assumed to hold preferences over X_1 and X_2 and make choices by maximizing utility U( ) representing those preferences subject to a constraint on income I. Swartz and Strand assume the quantity X_1 is a function of Z_1 and that no direct preferences exist for Z_1. Generalizing this specification, allow utility to be a function of Z_1, and suppose the consumer's problem is:

$$(1) \qquad \max_{X_1,X_2,N} \; U(X_1,X_2,Z_1(N)) \quad \text{subject to } P_1X_1 + P_2X_2 + cN = I.$$

Interior solutions are required suggesting that while some indirect mitigation might occur by substitution of X_2 for X_1, full mitigation is not feasible. If X_1 is interpreted as food and X_2 as all other goods and no product substitution is allowed, no indirect mitigation through substitution is allowed.

In this model, if we assume the state of safety N is exogenous, then its price can be set to zero and the willingness to pay (WTP) for an improvement in food safety can be evaluated as resulting from a change in N. Swartz and Strand determine WTP as the integral of the inverse demand function for X_1. We define WTP as the compensation necessary to equate the indirect utility functions evaluated before and after the change in the level of food safety. For example, where $V(I,N,P_1,P_2)$ defines the indirect utility function, WTP for a change from N′ to N″ could be defined as:

$$(2) \qquad V(I - WTP, N'', P_1, P_2) = V(I, N', P_1, P_2).$$

Alternatively, by total differentiation of the indirect utility function and constraining the variation in utility to be zero, WTP may be derived as:

$$(3) \qquad WTP = \partial I/\partial N = -(\partial V/\partial N)/(\partial V/\partial I).$$

This model can be generalized with no change in the approach to measuring WTP to allow for risk of illness by specifying the probability of illness as a function of the food safety level N, and perhaps personal characteristics of the consumer indicating state of health.

The usefulness and appropriateness of this case for valuation of changes in food safety can now be assessed. By design, the usefulness of the model is limited to cases where no mitigation occurs. In the case of UFBEs, past literature has considered this specification within the context of oysters and shellfish (Swartz and Strand 1981), milk (Foster and Just 1989, Smith et al. 1988), and apples (van Ravenswaay and Hoehn 1991a, 1991b). However, for these cases, the two product specification of the above model is clearly uninteresting since substitution and complementarity among foods is both likely and of interest as a possible form of mitigating behavior. Further, for many types of UFBEs, defensive actions are clearly feasible and the consumer choice model must be generalized to accommodate that possibility. Fat can be trimmed, fruit and vegetables can be washed, and meat can be stored properly. Where mitigation is feasible, either through product substitution or through defensive action, the level of exposure (N in the model above) becomes endogenous, rendering the Case 1 model misspecified for the problem under study.

Case 2: Exogenous Externality with Partial Mitigation

Coase (1960) recognized as early as 1960 that the effects of virtually any externality could be controlled by the affected individuals at least in part through defensive, mitigating, or averting actions. Coase (1960), Baumol (1972), Baumol and Oates (1971), Mishan (1977), and Shibata and Winrich (1983) presented reconsiderations of the implications of mitigating behavior for tax or subsidy solutions to externalities. Applied literature has considered three cases of behavioral reaction to externalities that are of interest to the problem of valuation of UFBEs. These cases include behavioral reactions (e.g., cleaning) to pollution, defensive actions taken to improve health, and the value of public goods provision when there exist private good substitutes or complements. To limit the scope of this discussion, focus will be placed on the first two areas of literature.

Courant and Porter (1981) explored the usefulness of averting expenditure as a measure of the benefits of reducing exposure to an externality where opportunity for averting action is feasible. Harford (1984) extended the Courant and Porter model to directly incorporate interaction between averting action and the level of exposure to the externality in determining the unit cost of averting action. The Harford model serves as a good starting point for motivation of models suitable for the analysis of consumer valuation of UFBEs effects. Harford defines the consumer's choice problem (equation 4 below) as a simple generalization of utility maximization subject to a budget constraint. Utility is affected by consumption of a numeraire good (X) and the level of cleanliness (C): U = U(X,C). Cleanliness is produced by the frequency of cleaning (F) and the extent of exposure to an externality (pollution, W): C = C(F,W). Cleaning and exposure also affect the unit cost of cleaning (q): q = q(F,W). Harford's model links exposure to the externality (W) and defensive action (cleaning, F) through a recursive, structural relation that generates an outcome (cleanliness) that affects utility. Harford's model also makes the cost of mitigation dependent on the exposure level. In the absence of such dependence, Harford's model would be interpretable as simply a multiple good variation of Case 1 described above. Harford's model may be summarized as follows:

(4)	max	$U = U(X,C)$	subject to
		$C = C(F,W)$	Cleanliness
		$q = q(F,W)$	Unit Cost of Cleaning
		$Y = X + qF$	Budget Constraint.

Harford derives the marginal willingness to pay for a change in the externality (W) by requiring that utility remains constant and choice remains optimal. Mathematically, the total differentials of utility and the budget constraint are set to zero simultaneously with the condition that the first order conditions are met. Harford finds that the marginal willingness to pay is equal to the change in total cost of cleanliness with respect to the change in pollution (as indicated by the second term in equation 5 below) and is determined by the marginal cost of cleaning, the rate of substitution between cleaning and pollution, and the cleaning frequency:

$$(5) \qquad (dY/dW)/_U = d(qF)/dW = (q + q_F F)(dF/dW)/_C + q_W F.$$

Harford's primary concern was to determine the usefulness of observed behavior such as the frequency and expense of cleaning for inferring the consumer's valuation of increased pollution. Courant and Porter (1981) showed that the benefits of pollution reduction could be measured by the average unit cost of cleaning times the decrease in cleaning induced by the decline in pollution. Harford's extension shows that marginal WTP can be measured by the change in defensive expenditure, though this is not, in general, simply (qdF/dW) as Courant and Porter found. Instead, marginal WTP in his model will vary with the level of pollution (since q_F varies with W). The conclusion is that averting expenditure cannot, in general, be measured by the change in averting behavior (e.g., cleaning) times the unit price of cleaning. Under simplified conditions, Harford shows that if the unit cost of cleaning depends on the level of cleanliness, rather than the level of pollution, then the Courant and Porter result emerges. The significance of these results is that change in total expenditure must be observed to measure WTP for a change in pollution, not simply change in mitigating behavior (e.g., F). Clearly, the nature of this result is of interest for the case of food safety where premia may exist for higher levels of safety. For example, where premia exist for certified pesticide-free produce, it is of interest to question whether such premia may be interpreted as a measure of WTP? Harford's results indicate that such premia would measure only one element of WTP.

Where averting or mitigating action is possible, the Harford model would seem to be of interest as a starting point for the measurement of consumer valuation of changes in UFBEs. Consider the case of pollution of drinking water. The question of consumer valuation of clean, safe water is immediately raised. Since bottled water is nearly universally available, and where it is not, boiling or filtration typically results in safety, consumers have defensive options. An attractive approach would be to use as an estimate of averting expenditure the quantity of boiling, filtration, or bottles of water times respective prices as a measure of consumer WTP. Harford's results would rule out such an approach as a measure of consumer WTP or true benefits when the unit cost of averting action is dependent on the extent of pollution and the extent of "cleaning" action. Since it is likely that unit costs would vary with pollution, Harford's proposed general approach would be necessary and use of averting expenditure would at best provide a lower bound estimate of true estimates.

Harrington and Portney (1987) reconsidered an extension of the question analyzed by Harford asking how data on direct and indirect costs of illness as well as on averting expenditures could be used to estimate benefits of a reduction in pollution. Harrington and Portney find that the true benefits of a reduction in a health threat posed by pollution exceeds the sum of the cost of illness and the change in defensive expenditures. This result contrasts with Harford's result which indicated that defensive or averting expenditures could either under- or over-estimate true benefits depending on the shape of the dose-response function. The Harrington and Portney model can be summarized as follows:

(6) $\max U(X,L,S)$ subject to

$S = S(D,P)$	Time Spent Ill
$M = mS(D,P)$	Cost of Illness
$T - L - S = 0$	Time Constraint
$I + wT - wL - wS(D,P) - X - D - mS(D,P) = 0$	Budget Constraint

where U is utility, X is the private consumption good, L is leisure, S is time spent ill, D is defensive expenditure, P is pollution, M is the cost of medical treatment, and w is the wage rate. In extensions, they add P to the utility function and allow w to vary with S.

Using the indirect utility function V = V(I,P,w), Harrington and Portney (1987) derive a compensating variation measure of marginal WTP for a reduction in P. Use of the indirect utility function assures that WTP is evaluated at optimal choices. By total differentiation of V( ), they find WTP (setting dV/dP = 0 and using the first order conditions):

$$\text{(7)} \quad \partial I/\partial P = -V_P/V_I = -S_P/S_D = (w + m)\, dS/dP - (U_S/\lambda)\, dS/dP + D_P.$$

The final expression on the right represents Harrington and Portney's decomposition of the benefit measure into three portions: (1) the money cost of illness, (2) the disutility cost of illness, and (3) defensive expenditures. This result clearly illustrates that cost of illness or defensive expenditure would underestimate true benefits.

As in the Harford model, the exposure to the externality (P) is specified by Harrington and Portney as strictly exogenous and independent of any consumption decision. This places the Harrington and Portney model within the context of Case 2. While consumer reaction is allowed through defensive action (D), as in Courant and Porter (1981), the unit cost of that action is fixed leaving the Harrington and Portney approach subject to Harford's criticisms. The Harrington and Portney model does take one step further than the Harford model in that income loss is allowed as a result of illness. Importantly, in an extension of their basic model, Harrington and Portney allow for the rate of loss (the wage rate) to vary with time spent ill. As do the Courant and Porter and the Harford models, the Harrington and Portney model establishes that benefit measurement is necessarily based on careful specification of the microeconomic decision problem faced by the consumer. Of great import is the specification of relations among defensive action and its cost, exposure, and its effect on utility.

The usefulness of the Harford or Harrington and Portney models for deriving measures of consumer valuation of UFBEs effects can now be assessed by nesting them in a common notation appropriate for the case under study. In particular, define:

$$\begin{aligned} \text{(8)} \quad & \max U = U(X,I,S) \quad \text{subject to} & \\ & I = I(D,E) & \text{Time Spent Ill} \\ & C = C(D,E) & \text{Cost of Illness} \\ & L + S + I \leq T & \text{Time Constraint} \\ & Y = X + qD - wL + C(D,E) & \text{Income Constraint} \end{aligned}$$

where X is the private consumption good, I is time spent ill, S is leisure, D is defensive action, E is exposure to a health debilitating externality, C is the cost of illness, L is labor time, T is total time, Y is income, and q and w are fixed unit prices. Harford's problem follows from equation 8 when leisure, labor, and illness time are dropped from the problem. Harrington and Portney's problem follows from equation 8 when the cost of illness C results from fixed unit cost m, i.e., C = mI(D,E) where m = i + w and i indicates the unit price of medical treatment of illness.

The essential feature of the Case 2 problem is that the level of the externality (E) is independent of consumer choice. For the UFBE problem, several further features are important to incorporate. First, it would seem reasonable to postulate that illness directly enters the utility function as in equation 8. Similarly, it would seem reasonable to specify an illness function as in equation 8 which is dependent on exposure to the foodborne effect and any defensive actions that are taken. As for the cost of illness, both the opportunity cost of time lost and the cost of treatment should be recognized. Harford's variable average cost of defensive action is appealing. In sum, the Case 2 model for UFBE analysis could be specified as an extension of equation 8:

(9)
$$\begin{aligned} &\max U = U(X,I,S) \quad \text{subject to} \\ &I = I(D,E) \\ &C = (m(D,E) + w)\, I(D,E) \\ &L + S + I \leq T \\ &Y = X - wL + qD + m(D,E)I(D,E). \end{aligned}$$

The differences between this model and those of Harford and Harrington and Portney are best appreciated from a consideration of its implications for the measurement of WTP. Using the indirect utility function to derive WTP:

(10)
$$dY/dE|_V = -V_E/V_Y$$

where V is evaluated at its initial value. Equation 10 provides the compensating variation, whereas when V is evaluated at the final value, equivalent variation results. Evaluating V_E and V_Y using the Lagrangian, the first-order conditions for optimal choice, and the total change in averting expenditures, equation 10 can be rewritten and decomposed to allow interpretation as follows:

(11)

$dY/dE|_V = (m + w)I_E + m_E I$	Marginal Cost of Illness
$- (1/\lambda)(U_I I_D D_E + U_I I_E)$	Money Value of Disutility
$+ (q + Dq_D + Im_D)D_E + q_I DI_E$	Marginal Defensive Expenditure

where λ is the Lagrangian multiplier.

The elements of the decomposition of WTP are directly interpretable as (1) the marginal cost of illness, (2) the marginal money value of disutility, and (3) the marginal defensive expenditure, each with respect to an exogenous change in exposure to the externality (E) which we interpret as UFBE exposure. Importantly, under general conditions, reliance on any one of the elements would result in an underestimation of the marginal benefit of the reduction in the externality. Further, following Harford, the marginal cost of defensive activity is not constant, but varies with the level of defensive action and the level of exposure. Equation 11 extends past results by clarifying that the disutility cost involves both a direct and an indirect effect that results from the defensive expenditure induced by an increase in exposure (D_E), a resulting decrease in illness (I_0), and increase in utility (U_I).

The consumer choice problem considered here for Case 2 and the derived WTP measure provide a solid microeconomic foundation for measurement of consumer valuation when consumer choices do not affect the level of exposure directly. For the case of UFBEs, it is difficult to identify examples which might fit this case. Consider the case where drinking water is polluted. If no other source of water were available, then water boiling or filtering could be appropriately thought of as mitigating behavior and the level of exposure could be viewed as exogenous and independent of consumption choices, although the extent of the effect is rendered endogenous through mitigation. However, such conditions seem unrealistic given widespread availability of bottled water. Purchases of bottled water would clearly affect the level of exposure implying the level of exposure is dependent on consumption decisions to substitute products. This condition would seem to be an important aspect of the choice problem relevant for valuation of food safety.

Case 3: Endogenous Externality with Full Mitigation

The measurement of consumer valuation of externalities when the consumer choice problem satisfies Case 3 can now be considered by simplifying and generalizing the model presented in equation 9. The key feature of the Case 3 problem is that the level of exposure to the externality is dependent on consumption decisions. For food consumption, this possibility would occur whenever the consumer is faced with an alternative product or action which can fully mitigate exposure.

Two possibilities occur which deserve examination. In the first, as in Case 2, exposure results from or is produced by an exogenous stimulus, say e, though mitigation is allowed with an endogenous, continuous defensive action, say D. In this case, the effect of the exposure (I) might be specified as $I = I(E(e,D))$. While e is exogenous, the individual can continuously vary the impact of the exposure by varying the mitigating action defined by D. The implication is that the exposure realized (E) and, therefore, the impact (I) are endogenous. This case might be viewed as an example of the situation faced by a consumer faced with produce with surface residues of a pesticide. The exposure level e is exogenously determined, though the realized exposure is dependent on defensive action D such as proper washing. These conditions are consistent with Case 2.

In Case 3, exposure may be fully mitigated through a binary decision to be exposed, e.g., as might result from the consumer's choice not to substitute an alternative product. Clearly, this is a case of great relevance to food safety since many food products are highly substitutable. In this case, multiple substitution possibilities imply mitigation could occur through substitution of other goods. Where a close substitute exists, complete avoidance of exposure or full mitigation may be feasible. In the UFBE application, these features necessarily take more specific form. For most situations, it could be expected that near perfect substitutes might exist, as in the case of organic produce. In this case, the consumer has a choice between two product types which are nearly perfect substitutes with respect to the consumption effects of the product which carry with it associated exposure to the "externality." Despite such near perfect substitution, the product alternative would be expected to have different prices since they would not be perfect substitutes when the externality is considered.

Past literature has not considered this case. Rather than extend the Case 2 specification to incorporate the features of Case 3, the following simplified Case 3 model for UFBE analysis, using a new notation, will be employed in order to retain focus on the implications of the unique features of the case:

(12)
$$\max U = U(X,Z,E) \quad \text{subject to}$$
$$X = X_u + X_e$$
$$X_u X_e = 0$$
$$E = E(X_e; e) \quad \text{where } E(0,e) = 0$$
$$Y = P_u X_u + P_e X_e + Z\ .$$

Again, U( ) is viewed as twice differentiable and strictly quasi-concave in X, Z, and E. In this specification, Z is defined as a typical private consumption good and its price is used as the numeraire to normalize all other prices. X_u and X_e are viewed as mutually exclusive consumption forms of a product. Importantly, however, X_u and X_e are considered perfect substitutes. In the form X_u, no externality exposure (E) is associated. In the form X_e, exposure is associated as described by the function E( ). Notably, we assume the level of exposure E is functionally related to the volume of consumption of X_e. The parameter e is defined as the efficiency of the transformation of characteristics of X_e into exposure E. We interpret e to measure the rate of exposure and to be exogenous. At one extreme this could be interpreted as simply an exogenous dosage rate of exposure. We purposely exclude any opportunity for direct defensive action from this case to sharpen the focus on product substitution as a means of full mitigation.

The first-order conditions for this problem immediately indicate the complication added by the roles of X_e and X_u in affecting utility. In brief, the mutual exclusivity of these two goods results in a discontinuity of both choice and the resulting dual functions since the first-order conditions require:

$$\text{(13)} \qquad \text{If } X_u = 0, \qquad U_X + U_E E_{Xe} - U_Z P_e = 0$$

$$U_X - U_Z P_u \leq 0$$

$$\text{If } X_e = 0, \qquad U_X - U_Z P_u = 0$$

$$U_X + U_E E_{Xe} - U_Z P_e \leq 0.$$

These conditions can be interpreted more conveniently by rewriting them in terms of the premium for X_u: $P_u - P_e$. By using the first-order condition inequality associated with each good when its optimal level is zero, the following rules may be written:

$$\text{(14)} \qquad \text{If } X_u = 0, \qquad m_{EZ} = -(U_E E_{Xe}/U_Z) \leq P_u - P_e$$

$$U_X + U_E E_{Xe} - U_Z P_e = 0$$

$$\text{If } X_e = 0, \qquad m_{EZ} = -(U_E E_{Xe}/U_Z) \geq P_u - P_e$$

$$U_X - U_Z P_u = 0.$$

From this perspective, it is clear that choice between product types depends on the magnitude of the marginal rate of substitution (m_{EZ}) between exogenous exposure (e) and other products (Z) relative to the magnitude of the relative premium (P_u - P_E). That is, the choice depends on the consumer's willingness to exchange units of E for units of Z as compared to the market's equilibrium rate of exchange of units of e for units of Z, as defined by the relative price P_u - P_e. As such, equation 14 provides an important basis for specifying an empirical model of the choice to switch between X_e and X_u. Further, it clarifies the role of premia for X_u vs. X_e.

Substitution of the optimal choices derived from equation 14 into the choice problem defined by equation 12 provides a definition of the indirect utility function. As in the case of choice, the indirect utility function is discontinuous and may be written:

(15) $$V = \sup \{V^e(P_e,Y,e/m_{EZ} \leq P_u - P_e), V^u(P_u,Y,e/m_{EZ} \geq P_u - P_e)\}.$$

V is defined as the supremum (or greatest) utility achievable and is conditional on the choice of X_u or X_e, as determined by the magnitude of m_{EZ} relative to that of $P_u - P_e$.

Within this notation, the total differential of the indirect utility function V can be taken to derive conditional WTP measures as follows:

(16) $$dY/de = - (\partial V^e(P_e,Y,e/m_{EZ} \leq P_u - P_e)/\partial e)/ (\partial V^e(P_e,Y,e/m_{EZ} \leq P_u - P_e)/\partial Y) \quad \text{if } X_u = 0, \text{ or}$$

$$- (\partial V^u(P_u,Y,e/m_{EZ} \geq P_u - P_e)/\partial e)/ (\partial V^u(P_u,Y,e/m_{EZ} \geq P_u - P_e)/\partial Y) \quad \text{if } X_e = 0.$$

These results indicate that for those consumers who consume the product X_e which has associated UFBEs, WTP will be positive and depend on the price of the good with UFBEs (P_e), income (Y), and the efficiency parameter e. For consumers that consume only X_u, the good free of UFBEs, WTP for a change in e is also positive, though in this case it is dependent on P_u, Y, and e. In either case, the WTP is conditional on the magnitude of m_{EZ} relative to $P_u - P_e$. For consumers who switch from X_u to X_e, at current levels of prices and income, their WTP is determined by the first line in equation 16, in the same way as it is for consumers who were already consuming X_e.

Before proceeding, it should be noted that the inequality conditions for choice or switching between X_e and X_u can be rewritten in terms of WTP. This follows from recognizing that:

(17) $$\partial V^e/\partial e = (\partial U/\partial E)(\partial E/\partial X_e)(\partial X_e/\partial e)$$

which implies that $m_{EZ} = - (\partial V^e/\partial e)/(\partial V^e/\partial Y) = WTP \mid X_e > 0 = WTP_e$ and allows equation 14 to be restated in terms of WTP_e:

(14') If $X_u = 0$, $$WTP_e \leq P_u - P_e$$

$$U_X + U_E E_{Xe} - U_Z P_e = 0$$

If $X_e = 0$, $$WTP_e \geq P_u - P_e$$

$$U_X - U_Z P_u = 0.$$

A Microeconomic Model of Consumer Choice and Valuation of UFBEs

Cases 2 and 3 presented above illustrate the implications of introducing each of two important features of the consumer choice problem when UFBEs are present in the marketplace. In this final section, a new model based on a synthesis of these features is introduced and a measure of WTP is derived and its decomposition analyzed. Of particular interest is to determine the implications of this model for the measurement of WTP for changes in exposure to UFBEs through consumption of contaminated food. The model presented abstracts from risk, the extension of the model to consider binary risk of exposure or uncertainty in exposure when consuming a potentially contaminated food product is trivial and would have no impact on the general nature of the results of this section. For example, introduction of a state preference approach for the binary risk case would be straightforward.

In the previous two cases, the consumer was allowed to endogenize the effect of exposure through one of two strategies: (1) partial mitigation through defensive action as in Case 2, or (2) full mitigation through substitution of alternative products as in Case 3. Clearly, in the case of food safety, the consumer can be expected to pursue both approaches whenever they are both feasible. Consumer choice in this case is defined by the following problem:

(18) $max\ U = U(X,Z,I,S)$ subject to

$$X = X_u + X_e$$

$$X_u X_e = 0$$

$$I = I(D,E)$$

$$E = E(X_e; e) \quad \text{where } E(0,e) = 0$$

$$Y = P_u X_u + P_e X_e + Z - wL + q(D,I)D + m(D,E)I(D,E) + wI(D,E)$$

$$L + S + I \leq T.$$

In this problem, the notation of Case 3 is preserved, however, several additional variables are introduced from Case 2 (equation 9) as follows: I is time spent ill, S is leisure time, D is defensive action, w is opportunity cost of time (set equal to the wage rate), L is time spent in the labor market, T is total time available, m is unit cost of illness (in excess of foregone wages), and q is unit cost of defensive action. As in Case 3, WTP can be written in terms of the indirect utility function and is conditional on whether X_u is positive or zero:

(19) $dY/de = WTP =$ $- (\partial V^e(P_e,w,T,Y,e/m_{EZ} \leq P_u - P_e)/\partial e)/$

$(\partial V^e(P_e,w,T,Y,e/m_{EZ} \leq P_u - P_e)/\partial Y)$ if $X_u = 0$

$- (\partial V^u(P_u,w,T,Y,e/m_{EZ} \geq P_u - P_e)/\partial e)/$

$(\partial V^u(P_u,w,T,Y,e/m_{EZ} \geq P_u - P_e)/\partial Y)$ if $X_e = 0$

where m_{EZ} is appropriately redefined relative to its definition for Case 3. As in Cases 2 and 3, WTP can be decomposed as:

(20) $WTP = dY/de =$

$m_E E_e I + (m + w)(I_D D_e + I_E E_e)$	Cost of Illness
$- (U_I - U_S)(I_E E_e)/\lambda$	Direct Disutility
$- (U_I - U_S)(I_D D_e)/\lambda$	Indirect Disutility
$+ (q + Im_D + q_D D + q_I D I_D)D_e$	Marginal Cost of Mitigation

where λ is the Lagrangian multiplier. As indicated, WTP can be decomposed into four parts. In general, measures on cost of illness will provide an inadequate basis for measurement of WTP. Equation 20 also highlights the inherent challenge of measuring WTP in the case under study. While data on the marginal cost of mitigation might be accessible, measures of disutility will typically be challenging to develop.

A further issue of interest is to consider the usefulness of readily available data reporting price premia for products that are perceived as not contaminated by an UFBE. Within the context of the present model, the issue is whether WTP can be measured using data reporting $P_u - P_e$. To consider this issue, the first-order conditions can be used to derive the inequality condition for $X_u > 0$, namely:

(21) $- ((U_I - U_S)I_E E_{Xe}/\lambda) + (m - w)I_E E_{Xe} + q_I D I_E E_{Xe} + m_E E_e I \geq P_u - P_e$

evaluated at $X_u = X_e = 0$. By substitution and use of WTP as expressed in equation 20, the following inequality can be derived:

(22) When $X_u > 0$, $WTP = dY/de \geq (P_u - P_e) + (U_I - U_S)(I_D D_e)/\lambda +$

$$(q + Im_D + q_D D + q_I D I_D)D_e.$$

In other words, when mitigation is feasible through defensive action, WTP will exceed the price premium P_u - P_e required by the market for the purchase of the product with no perceived UFBE content, i.e., X_u. Typically, the price premium will differ from WTP by the value of indirect disutility and the marginal cost of mitigation associated with the exposure (e). Only where mitigation is infeasible, i.e., $D_e = 0$, will the price premium reflect a lower bound for WTP.

Conclusions

The objective of this chapter was to reconsider what microeconomics has to say about the measurement of consumer valuation of UFBEs. The models considered focused on two aspects of the consumer choice problem not widely considered in the limited theoretical work published to date: (1) mitigating actions and (2) product substitution. The role and implications of risk were not considered here though they could be added to the models presented with little complication (see, e.g., Foster and Just 1989). The role of uncertainty could also be added to the models by generalizing preferences to allow for preference with respect to uncertainty. Undoubtedly, the resulting measures of WTP and their interpretation would be complicated by this extension.

A variety of conclusions can be drawn from the models presented here. First, the conditions assumed under Case 1 (exogenous exposure with no mitigation or product substitution) would seem of little interest as a foundation upon which to build a microeconomic theory of consumer choice in the presence of UFBEs. Only where the exposure affects all foods equally, and where mitigation is technically infeasible, would this case be relevant. In contrast, the conditions considered in Cases 2 and 3 would seem highly relevant to the consumer choice problem in the presence of UFBEs. An important conclusion drawn from Case 2 was that data reporting the cost of mitigating action (e.g., the cost of water filtration, boiling of meat, or scrubbing vegetables) will not, in general, provide an estimate of willingness to pay. In addition to those costs, the cost of illness and the money value of disutility of exposure must also be considered. Similarly, for Case 3, the premia for products perceived or certified as uncontaminated was shown to be only one element of willingness to pay.

The general model presented at the close of the previous section synthesizes the salient features of Cases 2 and 3 to present a comprehensive model of consumer choice when UFBEs are of concern. The associated measure of willingness to pay was presented and decomposed to indicate the nature of its determination. Components were shown to include the cost of illness, the disutility of exposure, and the marginal cost of mitigating actions. Perhaps, the most important conclusion that can be drawn from these results concerns the paradox of survey results which have indicated that consumers have high levels of concern, yet the premia they indicate they are willing to pay for uncontaminated food have often been found to be small. Equation 22 clarifies that the premia would be expected to be small relative to willingness to pay. This suggests that survey questions must carefully elicit all elements of consumer valuation acknowledging explicitly each of its components as identified in equation 22.

References

Baumol, W. J. 1972. On Taxation and the Control of Externalities. *American Economic Review* 52:307-322.

Baumol W. J. and W. E. Oates. 1971. The Use of Standards and Pricing for Protection of the Environment. *Swedish Journal of Economics* 73:42-54.

Coase, R. H. 1960. The Problem of Social Cost. *Journal of Law Economics* 3:1-44.

Cook, R. L. 1989. Challenges and Opportunities in the U.S. Fresh Produce Industry. Paper presented at the Food Distribution Research Society 30th Conference, Albuquerque, NM.

Courant, P. and R. Porter. 1981. Averting Expenditures and the Cost of Pollution. *Journal of Environmental Economics and Management* 8:321-329.

Food Marketing Institute. 1989. *1989 Trends: Consumer Attitudes and the Supermarket*. Washington, D.C.: Food Marketing Institute.

Foster, W. and R. E. Just. 1989. Measuring Welfare Effects of Product Contamination with Consumer Uncertainty. *Journal of Environmental Economics and Management* 17:266-283.

Harford, J. 1984. Averting Behavior and the Benefits of Reduced Soiling. *Journal of Environmental Economics and Management* 11:296-302.

Harrington, W. and P. R. Portney. 1987. Valuing Benefits of Health and Safety Regulations. *Journal of Urban Economics* 22:101-112.

Mishan, E. J. 1977. What is the Optimal Level of Pollution? *Journal of Political Economy* 82:104-107.

Ott, S. L. and A. Maligaya. 1989. An Analysis of Consumer Attitudes Toward Pesticide Use and the Potential Market for Pesticide Residue-Free Fresh Produce. Paper presented at the 1989 Southern Agricultural Economics Association Meetings, Nashville, TN.

Sachs, C., D. Blair, and C. Richter. 1987. Consumer Pesticide Concerns: A 1965 and 1984 Comparison. *The Journal of Consumer Affairs* 21:96-107.

Shibata, H. and J. S. Winrich. 1983. Control of Pollution When the Offended Defend Themselves. *Economica* 50:425-437.

Smith, M. E., E. O. van Ravenswaay, and S. R. Thompson. 1988. Sales Loss Determination in Food Contamination Incidents: An Application to Milk Bans in Hawaii. *American Journal of Agricultural Economics* 70(3):513-520.

Swartz, D. G. and I. E. Strand, Jr. 1981. Avoidance Costs Associated with Imperfect Information: The Case of Kepone. *Land Economics* 57:139-150.

van Ravenswaay, E. O. and J. P. Hoehn. 1991a. Contingent Valuation and Food Safety: The Case of Pesticide Residues in Food. East Lansing, MI: Michigan State University, Department of Agricultural Economics Staff Paper 91-13.

van Ravenswaay, E. O. and J. P. Hoehn. 1991b. The Impact of Health Risk on Food Demand: A Case Study of Alar and Apples. In *Economics of Food Safety*, ed. Julie A. Caswell, 155-174. New York, NY: Elsevier Science Publishing Company.

Weaver, Robert D., D. J. Evans, and A. E. Luloff. 1992. Pesticide Use in Tomato Production: Consumer Concerns and Willingness to Pay. *Agribusiness* 8:131-142.

Zind, T. 1990. *Fresh Trends 1990: A Profile of Fresh Produce Consumers.* The Packer Focus, 1989-90. Overland Parks, KS: Vance Publishing Company.